ASSOCIATION OF SCIENTISTS AND ENGINEERS

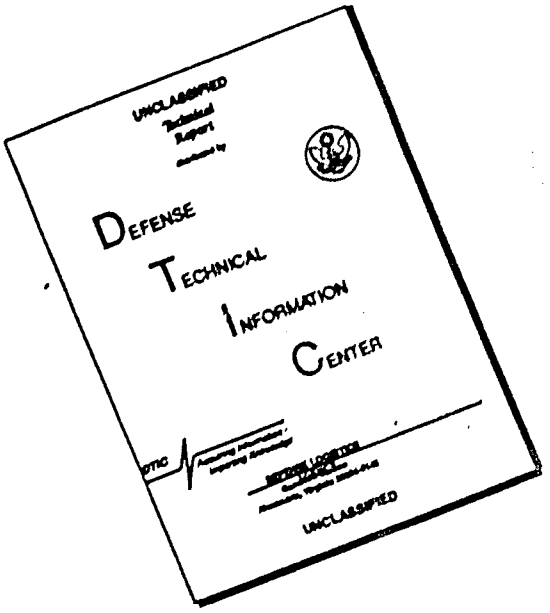
A STATISTICAL EXAMINATION OF WEIGHT AND KG MARGIN VALUES FOR U.S. NAVY SURFACE SHIPS

PAUL H. KERN

19TH ANNUAL TECHNICAL SYMPOSIUM 1982

ASSOCIATION OF SCIENTISTS AND ENGINEERS OF THE NAVAL SEA SYSTEMS COMMAND
DEPARTMENT OF THE NAVY – WASHINGTON, D.C. 20360

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

(1)

A STATISTICAL EXAMINATION OF WEIGHT AND KG MARGIN VALUES FOR U.S. NAVY SURFACE SHIPS

Paul H. Kern
SPECIAL PROJECTS SECTION (SEA 32122)
WEIGHT BRANCH
NAVAL SEA SYSTEMS COMMAND
Washington, D.C. 20362
APRIL, 1982

The views expressed herein are the personal opinions of the author and are not necessarily the official views of the Department of Defense or of the Department of the Navy

ABSTRACT

Effective weight and KG (height of vertical center of gravity above the keel) margins are an essential element of the U. S. Navy Weight Control Program. Margins are not only an engineering tool for making technical predictions, but are embodied in the fiscal process as well. The need for improvements in margin determination was recognized when the weight control program was formulated in 1961. The first improvement came with establishment of a formal margin policy in 1963. The values, restricted only to weight at that time, reflected the best corporate engineering judgment based on scattered and, in many cases, unverified weight growths. Because the shipbuilding process is relatively slow (compared to aircraft, land vehicle and missile production), it has taken fifteen years to accumulate a data base considered reasonable for a statistical study of margins. The data used in this paper are the product of the weight control program margin accounting system and represent a substantial improvement over the data used in 1963. This paper discusses the derivation of data and selection of appropriate statistical methodology in order to update the existing weight margin policy and establish a KG margin policy.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Table

Figure

Figure

1.0 INTRODUCTION

Effective weight and KG (height of vertical center of gravity above the keel) margins are an essential element of the U. S. Navy Weight Control Program as presented in reference a. Margins are not only an engineering tool for making technical predictions, but are embodied in the fiscal process as well. The need for improvements in margin determination was recognized when the weight control program was formulated in 1961. The first improvement came with establishment of a formal margin policy in 1963. The values, restricted only to weight at that time, reflected the best corporate engineering judgment based on scattered and, in many cases, unverified weight growths. Because the shipbuilding process is relatively slow (compared to aircraft, land vehicle and missile production), it has taken fifteen years to accumulate a data base considered reasonable for a statistical study of margins. The data used in this paper are the product of the weight control program margin accounting system and represent a substantial improvement over the data used in 1963. Raw weight and KG change data from the Preliminary/Contract Design (PD/CD) Phase and Procurement Phase (detail design and construction phase) for post weight control design have been collected and tabulated. These data have been reviewed and purified to include only design development changes.

2.0 DEFINITIONS

a. Groups 1 through 7 - The accumulated weight and KG for a ship design classified in accordance with the seven functional material groups of either the Ship Work Breakdown Structure (current requirement) or the BUSHIPS Consolidated Index of Material for Construction, Conversion and Repair (requirement before 1975). All material, hardware and components that are installed in the ship are accounted for in one of these seven groups.

b. Inclining Experiment - The procedure by which a ship's actual weight and center of gravity are computed from physical measurements taken while the ship is floating in water. At the time the measurements are taken, the ship is inventoried to determine what must be added or removed (by calculation) to produce Condition "A". This is the equivalent to Groups 1 - 7 at the time the inclining experiment is conducted. The actual amount of margin required is therefore represented by the differences in weight and KG between Condition "A" and Groups 1-7 estimated during design.

c. Preliminary Design Margin - A weight and KG allowance included in the weight estimate to account for changes caused by design development during preliminary design. This margin is carried in the conceptual design phase. No portion of the margin is consumed prior to the start of preliminary design, nor is any remaining margins carried over into the next design phase.

d. Contract Design Margin - A weight and KG allowance included in the weight estimate to account for changes caused by design development during contract design. This margin is carried in the conceptual and preliminary design phases. No portion of the margin shall be consumed prior to the start of contract design nor is any remaining margin carried over into the next design phase.

e. Design and Building Margin - A weight and KG allowance included in the weight estimate to account for design changes to the current weight due to ship construction drawing development, growth of contractor-furnished material, and omissions and errors in the estimate as well as differing shipbuilding practices, omissions and errors in the ship construction drawings, unknown mill tolerance, outfitting details, variations between the actual ship and its curves of form and similar differences. This margin is to compensate for all contractor-responsible discrepancies between the Contract Design Weight Estimate and the results of the inclining experiment, as well as tolerance for experimental variation in the inclining experiment. The weight and KG allowance is carried in the conceptual, preliminary, and contract design phases but no portion of this margin is consumed prior to award of the detail design and construction contract. The actual amount of design and building margin, as well as location, is subject to negotiation with the contractor for detail design and construction since it represents an allowance that is actually the contractor's responsibility.

f. Contract Modification Margin - A weight and KG allowance included in the weight estimate to account for changes caused by contract modifications issued during the detail design and construction phase. This margin is carried in the conceptual, preliminary and contract design phase weight estimates. No portion of this margin is consumed prior to award of the detail design and construction contract.

g. Government Furnished Material (GFM) Margin - A weight and KG allowance included in the weight estimate to account for changes caused by growth in non-nuclear GFM during the detail design and construction phase. The margin is carried in the conceptual, preliminary and contract design phase weight estimates. No portion of this margin is consumed prior to award of the detail design and construction contract.

h. Design Development - Changes in ship hardware, or material resulting from improved definition of systems or detailing of requirements by either NAVSEA or out-house sources, that lead to an iteration of the ship design. Significant, due to their exclusion from the definition, are characteristics changes that would change the configuration of the ships such as hull form and dimensions, stability criteria, speed, endurance, accommodations, ordnance, specific payload, and the like. However, when changes of this magnitude occur without characteristics changes, they must be considered as design development.

3.0 DATA DETERMINATION

Selection Criteria - No more than two ships from any one ship construction contract are included in the data. The margin values actually required are determined in tons and feet and then converted to percentages of change to Groups 1 through 7 total weight or KG values. This, in effect, eliminates the size of the ship as a variable. It is recognized that margin percentage values may vary with ranges of ship type displacements. However, at this time, insufficient number of data points are available to break out ranges of displacement for separate statistical studies. For information, Figures 1 through 8 are included. These figures are plotted as a percentage of weight or KG vs

original total Groups 1 through 7 weight or KG values.

PD/CD PHASE - For each data point, weight and KG changes were obtained by algebraically subtracting the original PD/CD weight estimate Groups 1 through 7 values from the final PD/CD weight estimate Groups 1 through 7 values. The resultant values represent weight changes in tons and percent and KG changes in feet and percent over the original values, modified where required, to exclude non-design development changes.

PROCUREMENT PHASE - For each data point, weight changes in tons and percent and KG changes in feet and percent were determined as follows:

a. Total Weight and KG Change - Total change values were obtained by algebraically subtracting the final Contract Design Weight Estimate total Groups 1 through 7 values from the Condition "A" values reflected in the Accepted Ship Report.

b. Contract Modification Weight and KG Changes - At the time of performance of the inclining experiment, the total weight and moment effect of all contract modifications issued for the ships are summarized by the contractor and included in the Accepted Ship Report. This summary value has been converted to weight and KG change as a percentage from the original Contract Design Weight Estimate total Groups 1 through 7 values. The percentage values obtained represent the actual contract modification margin required for the ship.

c. Government Furnished Material Weight and KG Changes - At the time of performance of the inclining experiment, the total weight and moment effect of all GFM changes are summarized by the contractor and included in the Accepted Ship Report. This summary value has been converted to weight and KG change as a percentage from the original Contract Design Weight Estimate total Groups 1 through 7 values. The percentage values obtained represent the actual GFM margins required for the ship.

d. Design Development Weight and KG Changes - All weight and moment changes not covered by contract modifications or GFM changes were charged to this account. The values were obtained by algebraically subtracting the contract modification changes and the GFM changes from the total weight and moment changes. The resultant summary values were converted to weight or KG change as a percentage from the original Contract Design Weight Estimate total Groups 1 through 7 value. The percentage values obtained represent the actual design and building margin required for the ship.

4.0 DERIVATION OF MARGIN PREDICTION METHODS

It is assumed that the available data represents random samples from normal populations. Standard experimental statistical methods are utilized for this study. Statistical tolerance limits furnish limits between, above, or below which one can confidently expect to find a prescribed proportion (P) of individual items of the population. Statistical tolerance limits are described in paragraph 2.5 of reference b. For the purpose of predicting

margin values for subsequent ship designs, the one-sided tolerance limit is used. This will provide for obtaining an upper value below which a proportion (P), at least, will lie. The appropriate equation for the one-sided tolerance limit is $X_u = \bar{X} + Ks$ where K represents a factor defined in standard statistical tables (specifically Table A-7 of reference b), and (s) represents an estimate of the population standard deviation. Thus, the sample mean ($\bar{X}$) which is an estimate of the true population mean and the sample standard deviation (s) were determined for each set of margin data. The following equations are applicable:

Given n values, each X value represented by $X_i = X_1, X_2, X_3, \ldots X_n$ (where i = 1 to i = n)

Average mean or expected

$$\bar{X} = \frac{1}{n}\left(\sum_{i=1}^{n} X_i\right)$$

By calculating each $X_i - \bar{X}$, the various deviations from the mean are determined. The standard deviation is determined by:

$$s = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{n-1}}$$

Preliminary/Contract Design Margin - The actual amount required for each ship is presented in Table 1. For both the weight and KG percentage values, the mean($\bar{X}$) and the standard deviation (s) were obtained. For the PD/CD weight margin, the $\bar{X}$ is 0.83% and the S.D. is $\pm$ 3.53%. For the PD/CD KG margin, the $\bar{X}$ is 2.67% and the S.D. is $\pm$ 3.42%. (It is noted that KG data was unavailable for point number 7.)

Procurement Phase Margins - The actual amounts required for design and building margin, contract modification margin and GFM margin for each ship are presented in Table 2. Several points (indicated by "*") are tabulated but not included in subsequent calculations (namely, points 5, 18, and 33). These points were omitted due to unvalidated changes in the contract modifications and GFM area. Therefore, none of the required margin values for those points could be accurately determined. The mean values ($\bar{X}$) and standard deviation values (s) for each margin are as follows:

	$\bar{X}$ %	s %
Design and Building Weight Margin	1.71	$\pm$ 3.58
Design and Building KG Margin	1.87	$\pm$ 3.10
Contract Modification Weight Margin	0.33	$\pm$ 1.10
Contract Modification KG Margin	0.18	$\pm$ 0.94
GFM Weight Margin	0.33	$\pm$ 0.87
GFM KG Margin	.0	$\pm$ 0.34

Statistical Tolerance Limits - For each of the values determined above, four different gamma (γ) (confidence levels) were selected. Values for X_u were determined for each of the gamma (γ) values of .99, .95, .90, and .75 and proportion (P) values of .999, .99, .95, 90, and .75 within each of the gamma (γ) values selected. These values for preliminary design and contract design phase are tabulated in Table 3 and for procurement phase are tabulated in Tables 4 and 5. Figures 9 through 16 are plots utilizing the data from Tables 3, 4, and 5.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The X_u data presented in Tables 3 and 4 for weight margin percentages reflect values that generally exceed those historically accepted by ship design managers. It is anticipated that the KG margin percentages reflected would also be unacceptable due to the influence of KG in the ship sizing process. Comments concerning margin value selections are as follows:

a. For gamma values of less than .75, it would be more effective to select margin values based on engineering judgment than to proceed down a pure statistical path which is blind to peculiarities of the design in hand. Therefore, a case for accepting a margin tolerance band spanning the mean value and the mean value plus one standard deviation value is clear. Generally, while the composite of the weight margin values from the original 1963 policy (see Figure 17) were adequate for most designs, the distribution of design and building, contract modification, and GFM weight margin was not reflected by the return data. Thus, it is recommended that the mean and mean plus one standard deviation values determined by this study be established as boundaries for subsequent designs for both the weight margin and KG margin. Application to specific margin selection is outlined below.

b. Figures 9 through 16 provide ranges of weight and KG percentage values to be used in preliminary design, contract design and procurement phases as appropriate. These figures and appropriate engineering narrative should be used as a basis for selecting ship weight and KG margins. While these figures provide statistical tolerance limits, it is recommended that the boundaries of margin values be between the mean value ($\bar{X}$) and the mean value plus one standard deviation. It should be the responsibility of the lead weight engineer to quantify the actual values to be included in the estimates. The values should be based on selection criteria similar to the following:

(1) Margins shall be selected on the basis of minimum anticipated growth. Generally, the total acquisition margin initially allocated (during the conceptual design phase) shall fall within the mean and the mean plus one standard deviation values.

(2) Acquisition margin allocations shall be based on the extent to which the new ship design departs from previous designs for which the history of weight and KG growth due to design development is known. Differences in design philosophy and overall size and configuration, as well as in subsystem features, shall be considered. Subsystems identical to or very much like those incorporated in one or more previous designs will tend to cause reduced margin allocations; subsystems in the early stages of development and quite unlike those previously installed will tend to cause increased margin allocations. A similar approach shall be utilized regarding design philosophy and overall ship size and configuration (i.e., similar ship types). Consultations with the Ship Design Manager and other engineers participating in the design shall be employed in assessing the effect that undefined (or developmental) systems, subsystems or interfaces might have relative to margin requirements.

(3) Acquisition margins will be assigned to compensate only for the growth due to design development. Such margins shall not generally be used to absorb weight or KG growths resulting from ship characteristics changes or from changes in subsystem design requirements and criteria. If such changes during design development do cause growth, the adequacy of acquisition margins previously allocated shall be re-evaluated.

(4) At the beginning of the design, margins for every subsequent phase of acquisition shall be based on the previous values for Groups 1 through 7 plus the margin allocated for the previous phase. For example, procurement margins shall be based on Groups 1 through 7 plus the margins for preliminary design and contract design. As the design proceeds, margins for future phases shall be re-evaluated.

(5) A special problem exists regarding selection of margins for preliminary design. Lack of historical data tracing weight and moment changes through the preliminary design phase prevents construction of meaningful graphs. However, the current level of design definition for preliminary design is essentially the same as beginning contract designs in the past. Therefore, margins for preliminary design shall be selected in conjunction with contract design margins, using graphs numbered 9 and 13. The total margins for both preliminary and contract design shall not exceed the constraints shown in those two graphs.

c. This study should be updated as additional return data is obtained. The results of this study and any revisions thereto should be included in any Navy policy instruction regarding weight and KG margin.

6.0 REFERENCES

a. Weight Control of Naval Ships, Volume 1 (NAVSEA S-9096-AA-WCM-010/(U)WT CNTRL dated October 1978

b. Experimental Statistics - National Bureau of Standards Handbook 91 issued August 1, 1963. Reprinted Oct. 1966

TABLE 1

CONTRACT DESIGN WEIGHT AND KG MARGIN

DATA POINT	SHIP NAME	PRELIM. DESIGN GR 1-7 WT	PRELIM. DESIGN KG	DISPL. CHANGE TONS	DISPL. CHANGE PCT.	KG CHANGE TONS	KG CHANGE PCT.
1	AE	9659.60	35.43	-211.50	-2.190	2.08	5.871
2	AFS	9203.70	32.60	-271.50	-2.950	2.19	6.718
3	AGS	2752.60	23.79	-110.10	-4.000	2.01	8.449
4	AO	8293.70	34.82	-92.10	-1.110	.77	2.211
5	AOE	18482.20	39.90	-92.70	-.502	.25	.627
13	CG	5283.30	0.00	-14.40	-.273	0.00	0.000
6	CGN	11968.00	27.70	296.90	2.481	1.10	3.971
14	CGN	6717.20	22.41	247.70	3.688	.22	.982
15	CGN	7963.00	22.20	189.20	2.376	.07	.315
7	CVA	55058.00	52.64	1618.00	2.939	N/A	N/A
8	DD	2597.90	18.70	-121.90	-4.692	-.25	-1.337
9	FF	1287.50	14.67	-3.50	-.272	.23	1.568
10	FF	1700.00	15.85	65.70	3.865	.90	5.678
11	FF	2408.00	16.37	139.90	5.810	.69	4.215
12	FFG	2476.00	16.72	112.80	4.556	.56	3.349
16	FFG	2403.00	20.40	48.00	1.998	.20	.980
17	LST	3238.00	20.69	231.30	7.143	-1.21	-5.848
18	LST	4422.00	21.84	70.00	1.583	1.16	5.311
19	SCS	9353.00	35.24	-446.00	-4.769	1.75	4.966

N/A = NOT AVAILABLE

TABLE 2

DATA POINT	SHIP TYPE	CGME GR 1-7	DISPLACEMENT CHANGES TO CGME (TONS AND PERCENT)								CGME KG	KG CHANGES TO CGME (FEET AND PERCENT)							
			D&B MARGIN		C.MOD. MARGIN		GFM MARGIN		TOTAL MARGIN			D&B MARGIN		C.MOD. MARGIN		GFM MARGIN		TOTAL MARGIN	
			TONS	PCT.	TONS	PCT.	TONS	PCT.	TONS	PCT.		FEET	PCT.	FEET	PCT.	FEET	PCT.	FEET	PCT.
1	AD	12803.5	360.5	2.82	-57.0	-.45	11.0	.09	314.5	2.46	40.73	.595	1.46	.350	.86	-.028	-.07	.910	2.23
2	AE	9449.1	156.9	1.66	43.0	.46	5.0	.05	204.9	2.17	37.51	-.228	-.61	.317	.85	-.057	-.15	.030	.08
3	AE	10038.6	89.4	.89	-271.0	-2.70	12.0	.12	-169.6	-1.69	36.67	1.597	4.36	-.603	-1.64	.028	.08	1.070	2.92
4	AFS	9462.6	-455.6	-4.81	126.6	1.34	-25.4	-.27	-354.4	-3.75	34.79	-.070	-.20	.204	.59	-.073	-.21	.070	.20
5	AFS	9363.9	-976.6	-10.43	750.3	8.01	-7.4	-.08	-233.7	-2.50	34.97	.450	1.29	-.165	-.47	.009	.03	.240	.69
6	AFS	9509.8	-477.0	-5.02	-2.5	-.03	7.3	.08	-472.2	-4.97	35.09	-.668	-1.90	-.084	-.24	.034	.10	-.720	-2.05
7	AGOR	2329.4	31.6	1.36	-12.0	-.52	0.0	0.00	19.6	.84	30.08	-.463	-1.54	-.066	-.22	0.000	0.00	-.530	-1.76
8	AGS	1923.7	35.5	1.85	-17.0	-.89	-.3	-.01	18.3	.95	21.29	.597	2.81	.123	.58	-.014	-.06	.710	3.33
9	AGS	1825.4	-32.4	-1.77	-2.6	-.14	-.1	-.00	-35.0	-1.92	21.22	.239	1.13	.260	1.23	-.014	-.07	.490	2.31
10	AKA	10314.7	-192.7	-1.87	-58.0	-.56	-16.0	-.16	-266.7	-2.59	36.05	2.191	6.08	-.153	-.42	-.050	-.14	2.000	5.55
11	AOE	18931.8	1065.2	5.63	-171.0	-.90	-5.0	-.03	889.2	4.70	39.80	.875	2.20	-.596	-1.50	-.020	-.05	.300	.75
12	AOE	19478.3	635.7	3.26	5.0	.03	-105.0	-.54	535.7	2.75	40.53	1.858	4.58	.164	.40	-.075	-.18	1.780	4.39
13	AOR	12490.0	140.0	1.12	57.0	.46	36.0	.29	233.0	1.87	36.40	.983	2.70	.131	.36	-.036	-.10	1.070	2.94
14	AOR	12490.0	202.0	1.62	60.0	.48	-17.0	-.14	245.0	1.96	36.40	1.670	4.59	.008	.02	.008	.02	1.680	4.62
15	AOR	12359.1	413.9	3.35	18.0	.15	5.0	.04	436.9	3.53	37.81	.279	.74	-.015	-.04	-.004	-.01	.260	.69
16	AS	12765.9	1011.1	7.92	84.0	.66	42.0	.33	1137.1	8.91	41.24	1.764	4.28	-.022	-.05	.013	.03	1.740	4.22
17	AS	12769.8	1012.2	7.93	7.0	.05	30.0	.23	1049.2	8.22	41.17	1.567	3.81	.081	.20	.013	.03	1.650	4.01
18	ASR	2722.7	522.3	19.18	360.0	13.22	67.0	2.46	949.3	34.87	28.00	-.996	-3.56	2.714	9.69	.279	1.00	1.610	5.75
19	ATS	2165.1	95.8	4.43	-47.4	-2.19	95.7	4.42	144.1	6.66	20.75	1.006	4.85	.164	.79	-.159	-.76	.980	4.72
29	CG	5268.9	-71.9	-1.37	96.5	1.83	6.3	.12	30.9	.59	23.05	.217	.94	.291	1.26	.003	.01	.510	2.21
30	CG	5268.9	33.5	.64	94.5	1.79	-8.8	-.17	119.3	2.26	23.05	.118	.51	.150	.65	-.047	-.20	.220	.95
31	CGN	8152.2	-376.7	-4.62	73.5	.90	32.4	.40	-270.8	-3.32	22.27	.930	4.18	.233	1.04	-.087	-.39	1.070	4.80
28	CVA	56676.0	1538.0	2.71	52.0	.09	2.0	.00	1592.0	2.81	52.64	1.325	2.52	-.269	-.55	.008	.01	1.050	1.99
44	CVAN	71027.0	1416.8	2.00	290.2	.41	0.0	0.00	1709.0	2.41	52.30	-.807	-1.54	.014	.03	0.000	0.00	-.790	-1.51
21	FF	2535.0	-83.0	-3.27	12.0	.47	11.0	.43	-60.0	-2.37	17.17	.250	1.46	.088	.51	.060	.35	.400	2.33
22	FF	2535.0	-103.8	-4.09	15.0	.59	22.5	.89	-66.3	-2.61	17.18	-.052	-.30	.127	.74	.097	.56	.180	1.05
23	FF	2870.9	111.1	3.87	48.0	1.67	14.0	.49	173.1	6.03	18.90	.014	.07	-.032	-.17	-.003	-.02	-.020	-.11
24	FF	2870.9	136.1	4.74	55.0	1.92	-12.0	-.42	179.1	6.24	18.90	.135	.71	.013	.07	-.060	-.32	.090	.48
25	FF	2870.9	51.1	1.78	-5.1	-.18	7.4	.26	53.4	1.86	18.90	.377	1.99	.135	.72	-.055	-.29	.190	1.01
26	FF	2870.9	32.6	1.14	56.8	1.98	28.7	1.00	118.1	4.11	18.90	-.023	-.12	.003	.02	-.125	-.66	-.140	-.74
27	FF	2948.0	30.8	1.04	-1.2	-.04	10.3	.35	39.9	1.35	18.90	.420	2.22	.004	.02	-.034	-.18	.390	2.06
28	FFG	2588.8	-79.8	-3.08	86.0	3.32	56.0	2.16	62.2	2.40	17.28	.994	5.75	-.159	-.92	-.021	-.12	.760	4.40
32	LCC	11463.7	251.3	2.19	66.0	.58	-23.0	-.20	294.3	2.57	36.99	1.651	4.46	-.450	-1.22	-.055	-.15	1.150	3.11
33	LCU	182.1	23.2	12.71	-5.6	-3.05	0.0	0.00	17.6	9.67	6.03	.469	7.77	-.013	-.22	0.000	0.00	.470	7.79
34	LCU	194.2	-3.7	-1.90	.3	.15	.0	.01	-3.4	-1.75	6.05	.771	12.74	-.009	-.15	-.000	-.01	.760	12.56
35	LKA	9973.3	187.7	1.88	24.0	.24	-9.0	-.09	202.7	2.03	35.91	2.939	8.18	-.007	-.02	-.028	-.08	2.900	8.08
36	LPD	8381.8	304.2	3.63	132.0	1.57	52.0	.62	488.2	5.82	33.07	.072	.22	.116	.35	.240	.72	.410	1.24
37	LPD	8381.8	591.4	7.06	110.5	1.32	7.4	.09	709.2	8.46	33.07	-.030	-.09	-.220	-.67	.006	.02	-.230	-.70
38	LPD	8377.7	560.6	6.69	-39.4	-.47	31.1	.37	552.3	6.59	32.97	.525	1.59	.202	.61	.123	.37	.830	2.52
39	LPD	8377.7	564.4	6.74	4.8	.06	31.1	.37	600.3	7.17	32.97	-.042	-.13	.029	.09	.123	.37	.100	.30
40	LPD	8159.9	567.4	6.95	-54.8	-.67	3.4	.04	516.0	6.32	31.63	1.043	3.30	.185	.59	-.002	-.01	1.220	3.86
41	LPH	10544.6	549.4	5.19	61.0	.58	1.0	.01	611.4	5.78	37.79	.169	.45	-.084	-.22	.001	.00	.090	.24
42	LSD	8030.6	-99.9	-1.23	16.4	.20	-8.5	-.11	-91.0	-1.13	31.77	-.826	-2.60	.008	.02	-.032	-.10	-.850	-2.68
43	PG	175.1	2.1	1.21	-.5	-.26	4.4	2.50	6.0	3.44	9.70	.005	.05	.415	4.28	.126	1.30	.530	5.46

TABLE 3

PRELIMINARY/CONTRACT DESIGN WEIGHT MARGIN — NO. DATA POINTS = 19

P VALUE	MEAN (X BAR)	STD. DEV.	GAMMA VALUES (γ) K(.75)	K(.90)	K(.95)	K(.99)	XU VALUES K(.75)	K(.90)	K(.95)	K(.99)
.75			.870	1.058	1.183	1.450	3.901	4.565	5.006	5.949
.90			1.536	1.781	1.949	2.315	6.252	7.117	7.710	9.002
.95	.83	3.53	1.942	2.228	2.423	2.855	7.685	8.695	9.383	10.908
.99			2.710	3.078	3.331	3.893	10.396	11.695	12.588	14.572
.999			3.577	4.041	4.364	5.078	13.457	15.095	16.235	18.755

PRELIMINARY/CONTRACT DESIGN KG MARGIN — NO. DATA POINTS = 18

P VALUE	MEAN (X BAR)	STD. DEV.	GAMMA VALUES (γ) K(.75)	K(.90)	K(.95)	K(.99)	XU VALUES K(.75)	K(.90)	K(.95)	K(.99)
.75			.876	1.071	1.200	1.481	5.666	6.333	6.774	7.735
.90			1.544	1.800	1.974	2.357	7.950	8.826	9.421	10.731
.95	2.67	3.42	1.951	2.249	2.453	2.906	9.342	10.362	11.059	12.609
.99			2.723	3.106	3.370	3.961	11.983	13.293	14.195	16.217
.999			3.595	4.078	4.415	5.167	14.965	16.617	17.769	20.341

TABLE 4

DESIGN AND BUILDING WEIGHT MARGIN — NO. DATA POINTS = 41

P VALUE	MEAN (X BAR)	STD. DEV.	GAMMA VALUES (γ) K(.75)	K(.90)	K(.95)	K(.99)	XU VALUES K(.75)	K(.90)	K(.95)	K(.99)
.75			.803	.923	.999	1.154	4.585	5.014	5.286	5.841
.90			1.445	1.598	1.697	1.902	6.883	7.431	7.785	8.519
.95	1.71	3.58	1.834	2.010	2.126	2.365	8.276	8.906	9.321	10.177
.99			2.568	2.793	2.941	3.250	10.903	11.709	12.239	13.345
.999			3.395	3.679	3.866	4.255	13.864	14.881	15.550	16.943

CONTRACT MODIFICATION WEIGHT MARGIN — NO. DATA POINTS = 41

P VALUE	MEAN (X BAR)	STD. DEV.	GAMMA VALUES (γ) K(.75)	K(.90)	K(.95)	K(.99)	XU VALUES K(.75)	K(.90)	K(.95)	K(.99)
.75			.803	.923	.999	1.154	1.213	1.345	1.429	1.599
.90			1.445	1.598	1.697	1.902	1.920	2.088	2.197	2.422
.95	.33	1.10	1.834	2.010	2.126	2.365	2.347	2.541	2.669	2.932
.99			2.568	2.793	2.941	3.250	3.155	3.402	3.565	3.905
.999			3.395	3.679	3.866	4.255	4.065	4.377	4.583	5.011

GFM WEIGHT MARGIN — NO. DATA POINTS = 41

P VALUE	MEAN (X BAR)	STD. DEV.	GAMMA VALUES (γ) K(.75)	K(.90)	K(.95)	K(.99)	XU VALUES K(.75)	K(.90)	K(.95)	K(.99)
.75			.803	.923	.999	1.154	1.029	1.133	1.199	1.334
.90			1.445	1.598	1.697	1.902	1.587	1.720	1.806	1.985
.95	.33	.87	1.834	2.010	2.126	2.365	1.926	2.079	2.180	2.388
.99			2.568	2.793	2.941	3.250	2.564	2.760	2.889	3.158
.999			3.395	3.679	3.866	4.255	3.284	3.531	3.693	4.032

TABLE 5

DESIGN AND BUILDING KG MARGIN — NO. DATA POINTS = 41

P VALUE	MEAN (X BAR)	STD. DEV.	GAMMA VALUES (γ) K(.75)	K(.90)	K(.95)	K(.99)	XU VALUES K(.75)	K(.90)	K(.95)	K(.99)
.75			.803	.923	.999	1.154	4.359	4.731	4.967	5.447
.90			1.445	1.598	1.697	1.902	6.350	6.824	7.131	7.766
.95	1.87	3.10	1.834	2.010	2.126	2.365	7.555	8.101	8.461	9.202
.99			2.568	2.793	2.941	3.250	9.831	10.528	10.987	11.945
.999			3.395	3.679	3.866	4.255	12.395	13.275	13.855	15.061

CONTRACT MODIFICATION KG MARGIN — NO. DATA POINTS = 41

P VALUE	MEAN (X BAR)	STD. DEV.	GAMMA VALUES (γ) K(.75)	K(.90)	K(.95)	K(.99)	XU VALUES K(.75)	K(.90)	K(.95)	K(.99)
.75			.803	.923	.999	1.154	.935	1.048	1.119	1.265
.90			1.445	1.598	1.697	1.902	1.538	1.682	1.775	1.968
.95	.18	.94	1.834	2.010	2.126	2.365	1.904	2.069	2.178	2.403
.99			2.568	2.793	2.941	3.250	2.594	2.805	2.945	3.235
.999			3.395	3.679	3.866	4.255	3.371	3.638	3.814	4.180

GFM KG MARGIN — NO. DATA POINTS = 41

P VALUE	MEAN (X BAR)	STD. DEV.	GAMMA VALUES (γ) K(.75)	K(.90)	K(.95)	K(.99)	XU VALUES K(.75)	K(.90)	K(.95)	K(.99)
.75			.803	.923	.999	1.154	.273	.314	.340	.392
.90			1.445	1.598	1.697	1.902	.491	.543	.577	.647
.95	0.00	.34	1.834	2.010	2.126	2.365	.624	.683	.723	.804
.99			2.568	2.793	2.941	3.250	.873	.950	1.000	1.105
.999			3.395	3.679	3.866	4.255	1.154	1.251	1.314	1.447

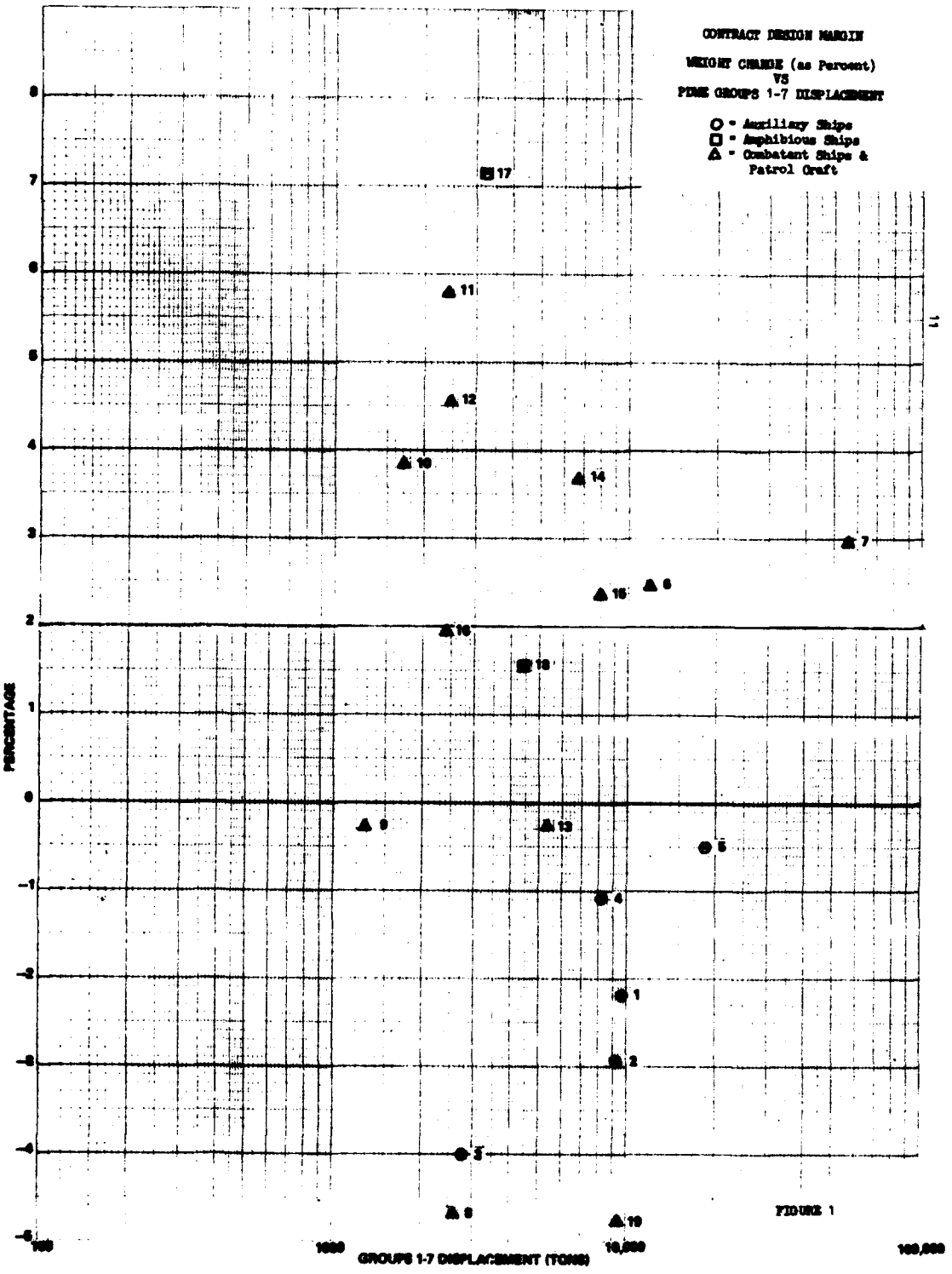

CONTRACT DESIGN MARGIN
WEIGHT CHANGE (as Percent)
VS
FIRE GROUPS 1-7 DISPLACEMENT
○ = Auxiliary Ships
□ = Amphibious Ships
△ = Combatant Ships & Patrol Craft
PERCENTAGE
GROUPS 1-7 DISPLACEMENT (TONS)
17
11
12
10
14
7
15
8
16
18
9
13
5
4
1
2
3
6
19

FIGURE 1

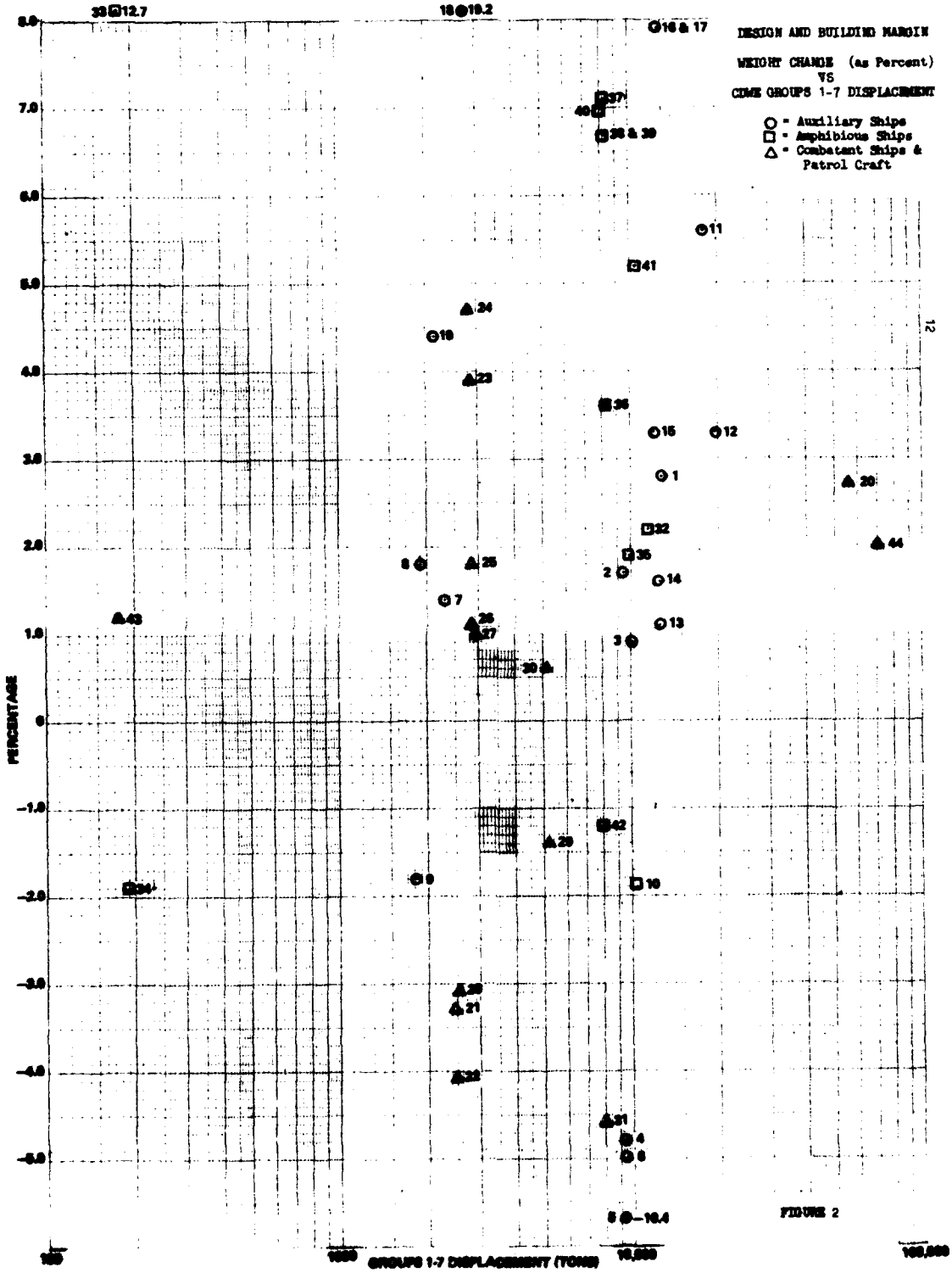

DESIGN AND BUILDING MARGIN
WEIGHT CHANGE (as Percent)
VS
CDME GROUPS 1-7 DISPLACEMENT
○ = Auxiliary Ships
□ = Amphibious Ships
△ = Combatant Ships & Patrol Craft
PERCENTAGE
GROUPS 1-7 DISPLACEMENT (TONS)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
-3.0
-4.0
-5.0
33 12.7
18 19.2
16 & 17
37
40
38 & 39
11
41
24
19
23
36
15
12
1
20
22
44
8
25
35
2
14
7
43
26
27
13
3
30
42
29
9
10
34
39
21
22
31
4
6
5 -10.4

FIGURE 2

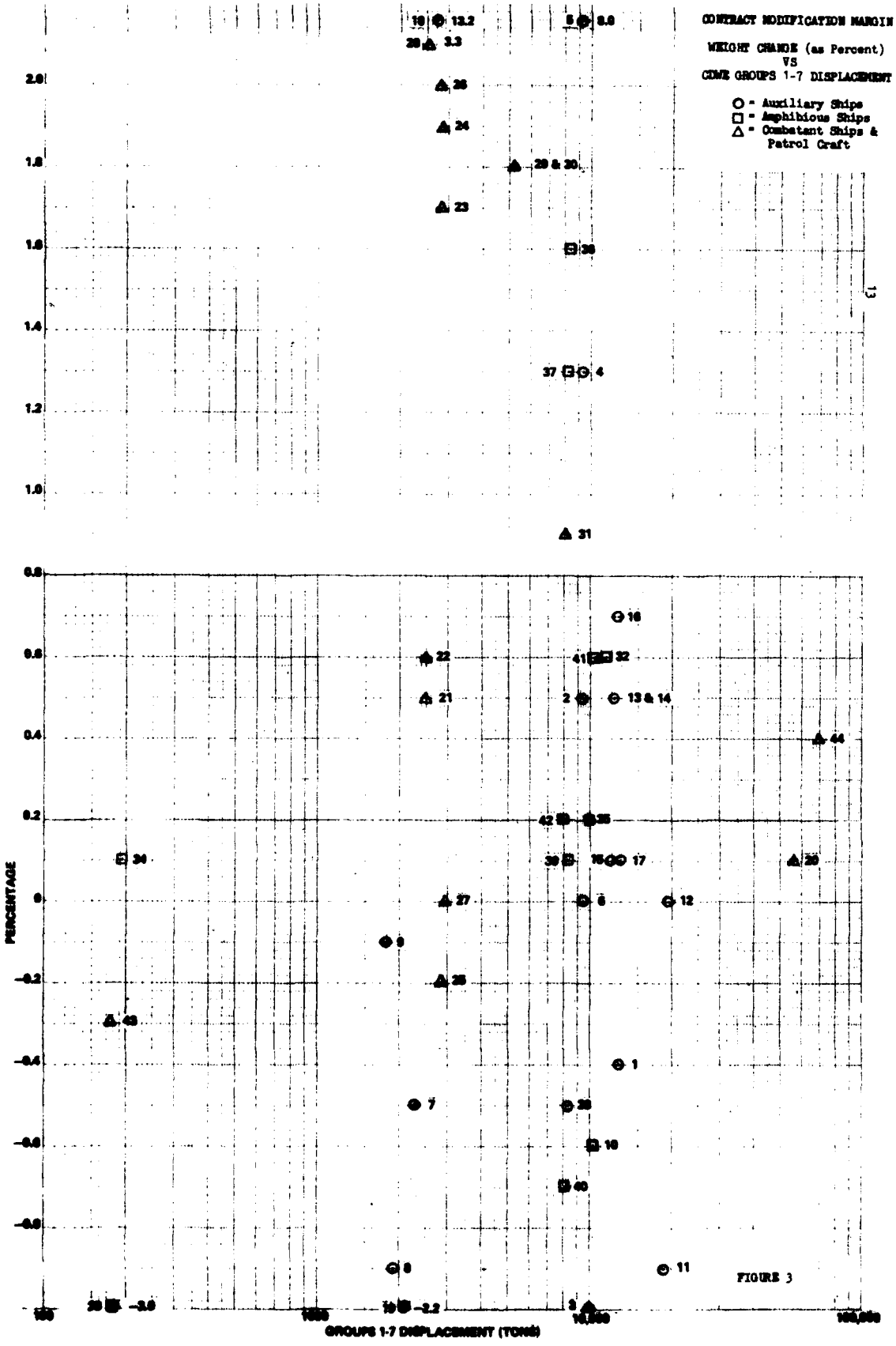
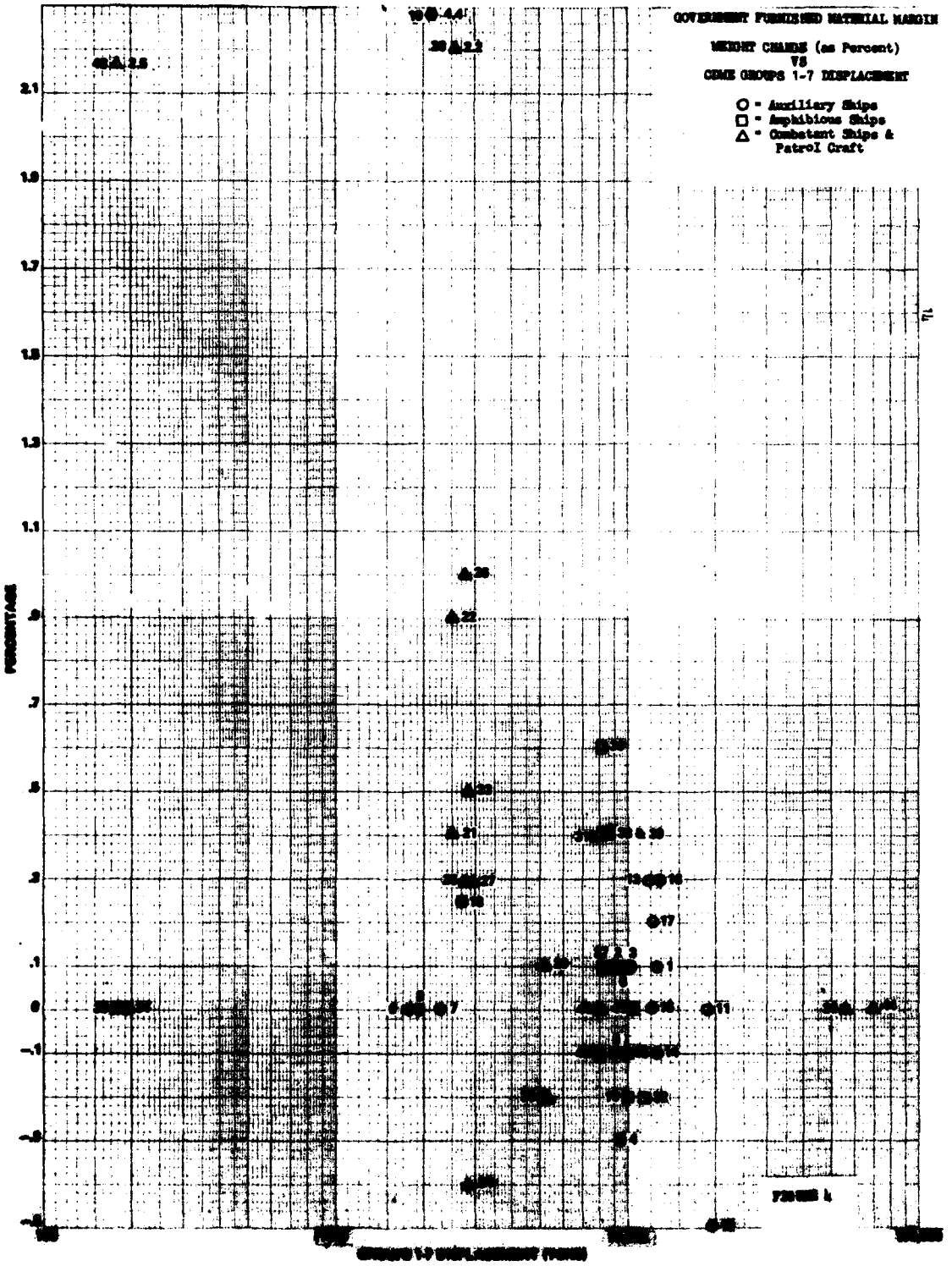

CONTRACT MODIFICATION MARGIN
WEIGHT CHANGE (as Percent)
VS
CDWE GROUPS 1-7 DISPLACEMENT
○ - Auxiliary Ships
□ - Amphibious Ships
△ - Combatant Ships & Patrol Craft
PERCENTAGE
GROUPS 1-7 DISPLACEMENT (TONS)

FIGURE 3


GOVERNMENT FURNISHED MATERIAL MARGIN
WEIGHT CHANGE (as Percent)
VS
CEMC GROUPS 1-7 DISPLACEMENT
O - Auxiliary Ships
□ - Amphibious Ships
△ - Combatant Ships & Patrol Craft
PERCENTAGE
2.1
1.9
1.7
1.5
1.3
1.1
.9
.7
.5
.3
.1
0
-.1
-.3
-.5
FIGURE 4

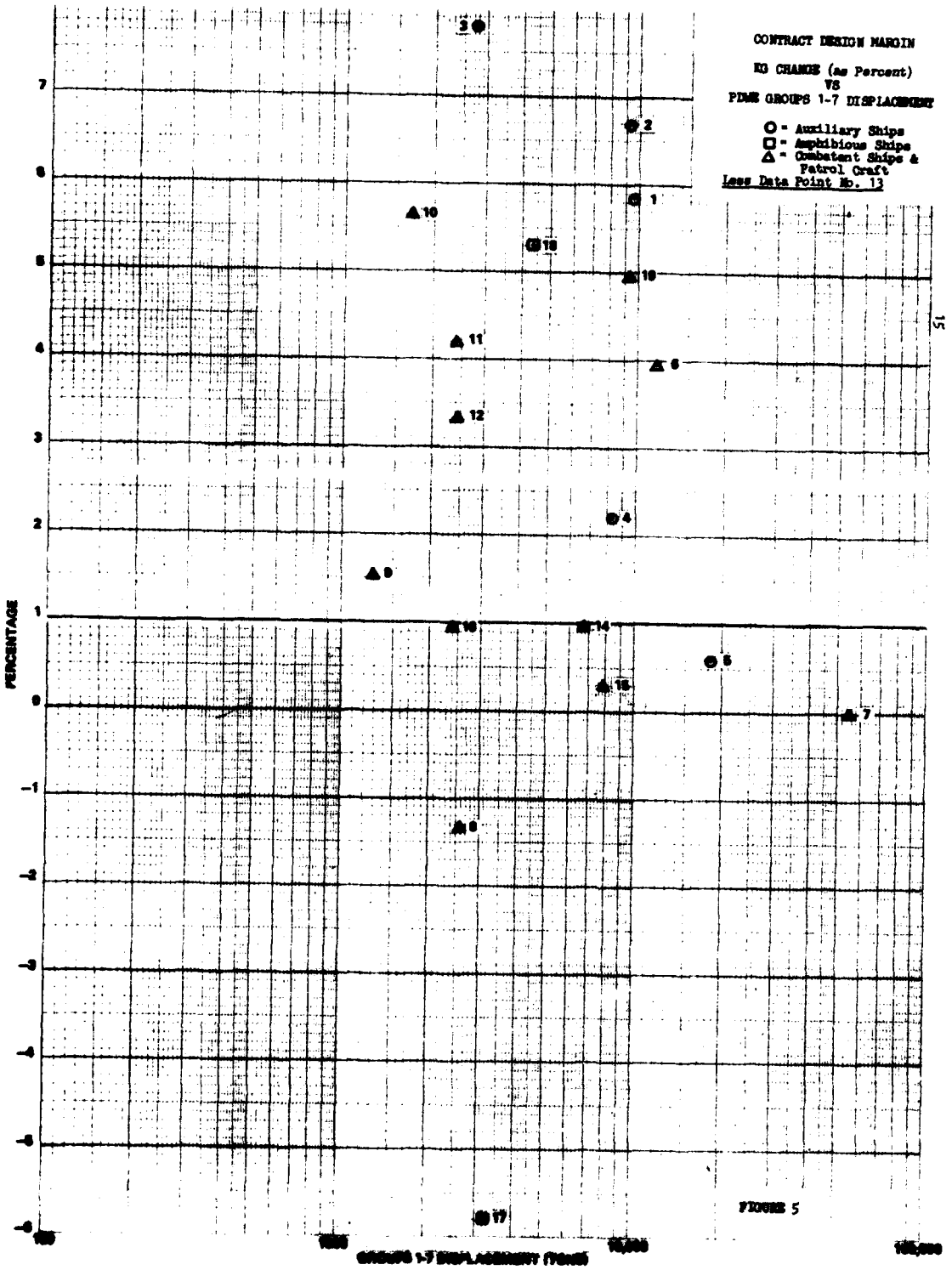

CONTRACT DESIGN MARGIN
KG CHANGE (as Percent)
VS
FIRM GROUPS 1-7 DISPLACEMENT
O - Auxiliary Ships
□ - Amphibious Ships
△ - Combatant Ships & Patrol Craft
Less Data Point No. 13
PERCENTAGE
GROUPS 1-7 DISPLACEMENT (TONS)

FIGURE 5

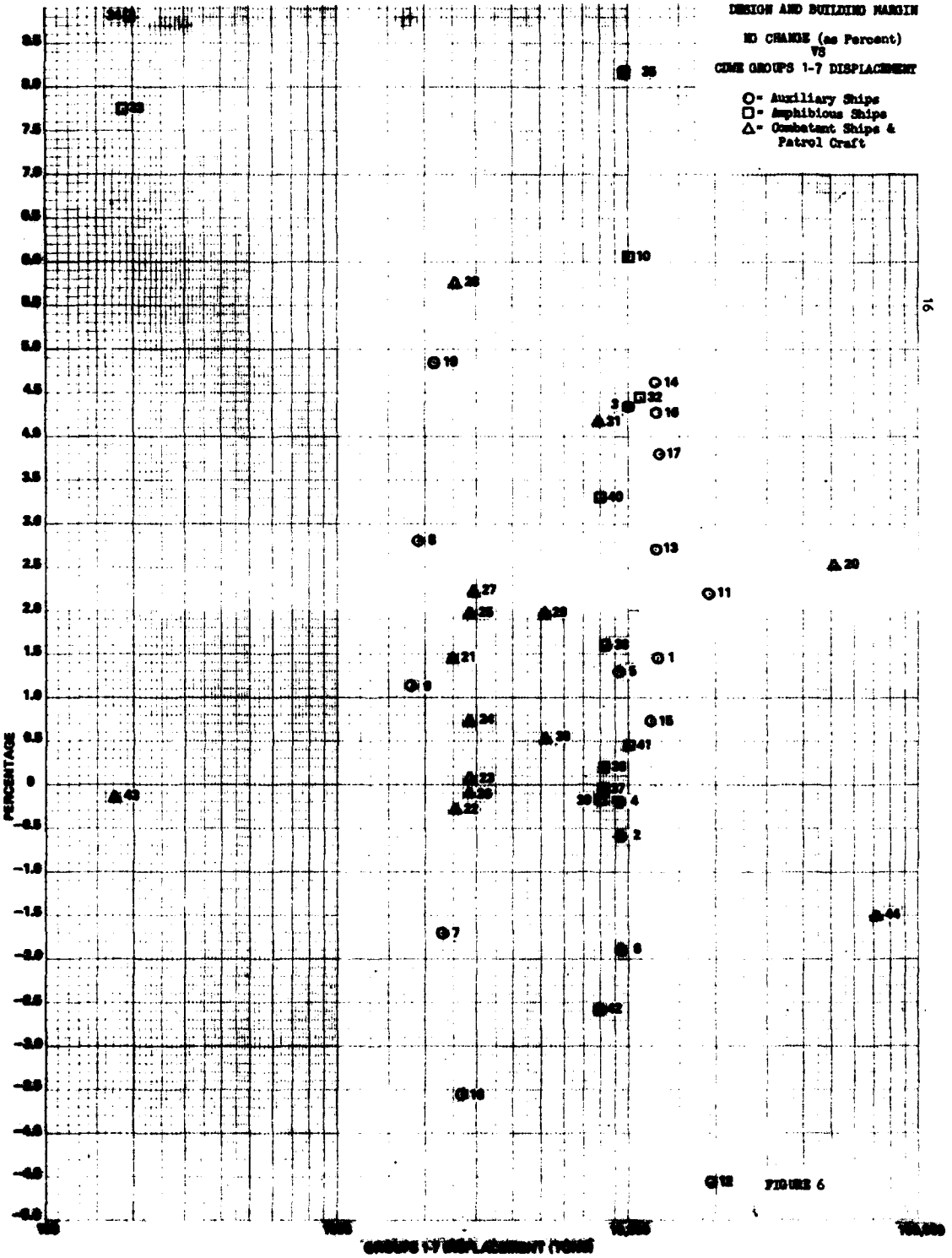

DESIGN AND BUILDING MARGIN
NO CHANGE (as Percent)
VS
CDNE GROUPS 1-7 DISPLACEMENT
O- Auxiliary Ships
□- Amphibious Ships
△- Combatant Ships & Patrol Craft
PERCENTAGE

FIGURE 6

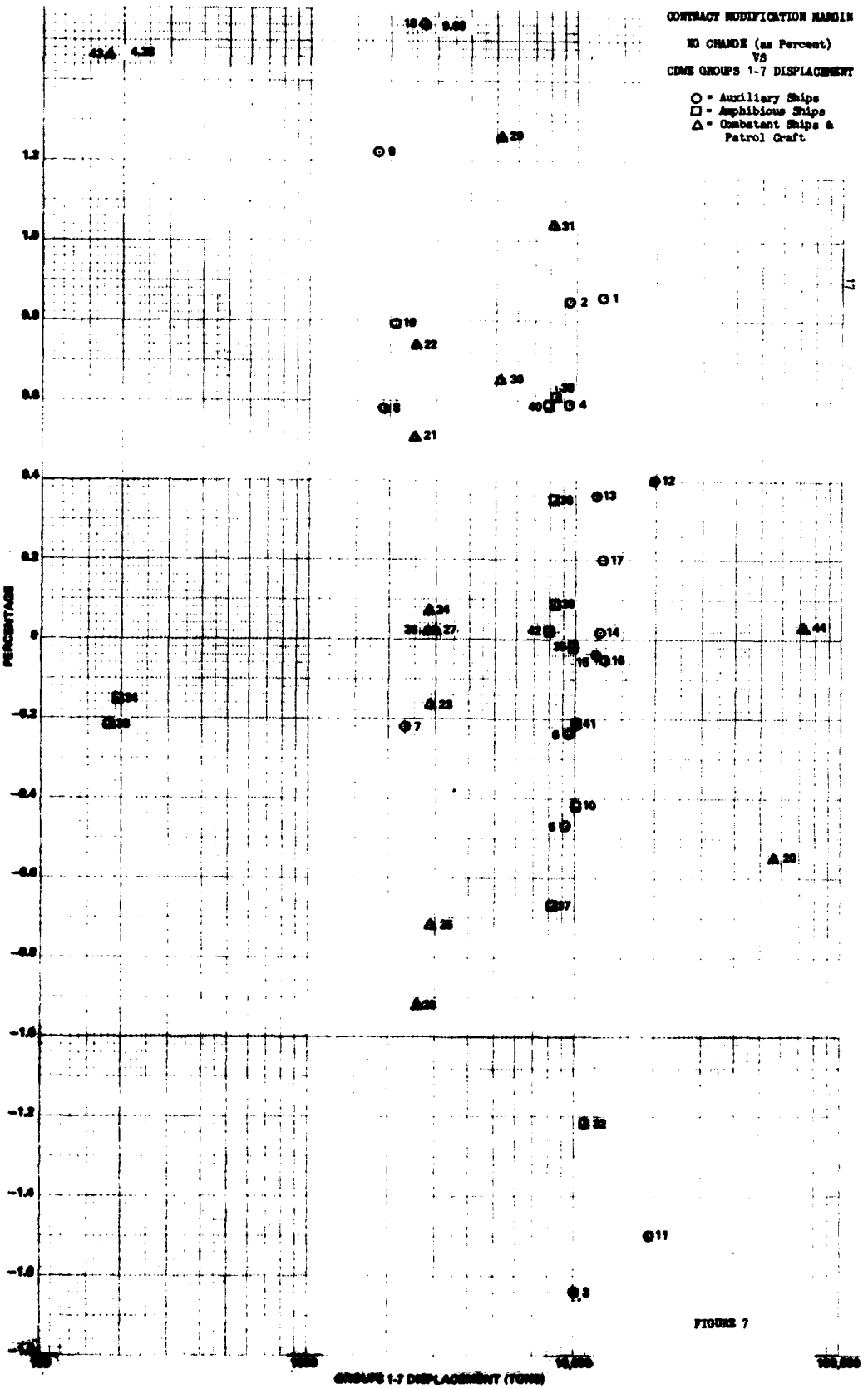

CONTRACT MODIFICATION MARGIN
NO CHANGE (as Percent)
VS
CDNS GROUPS 1-7 DISPLACEMENT
○ = Auxiliary Ships
□ = Amphibious Ships
△ = Combatant Ships & Patrol Craft
PERCENTAGE
GROUPS 1-7 DISPLACEMENT (TONS)

FIGURE 7

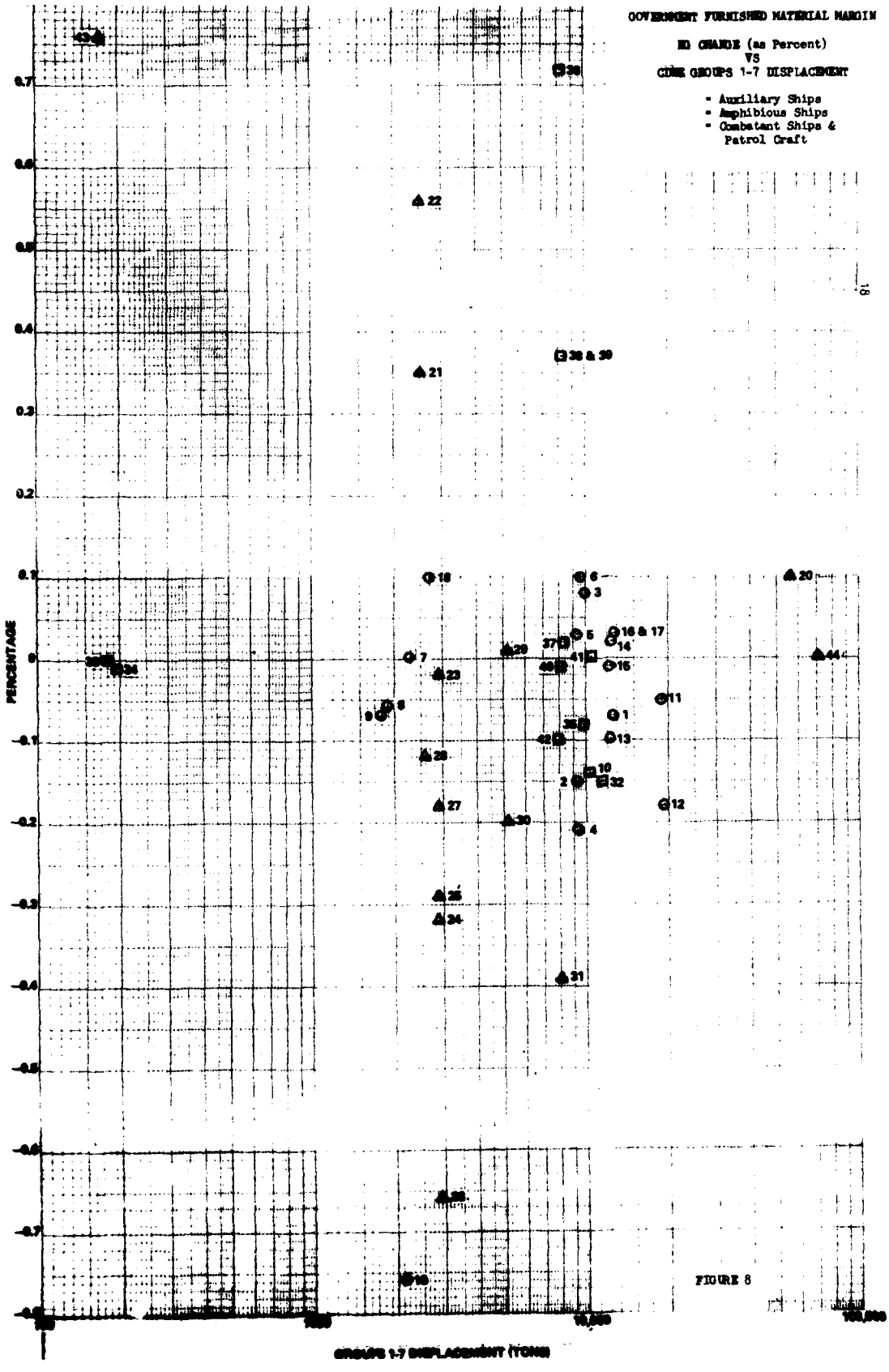
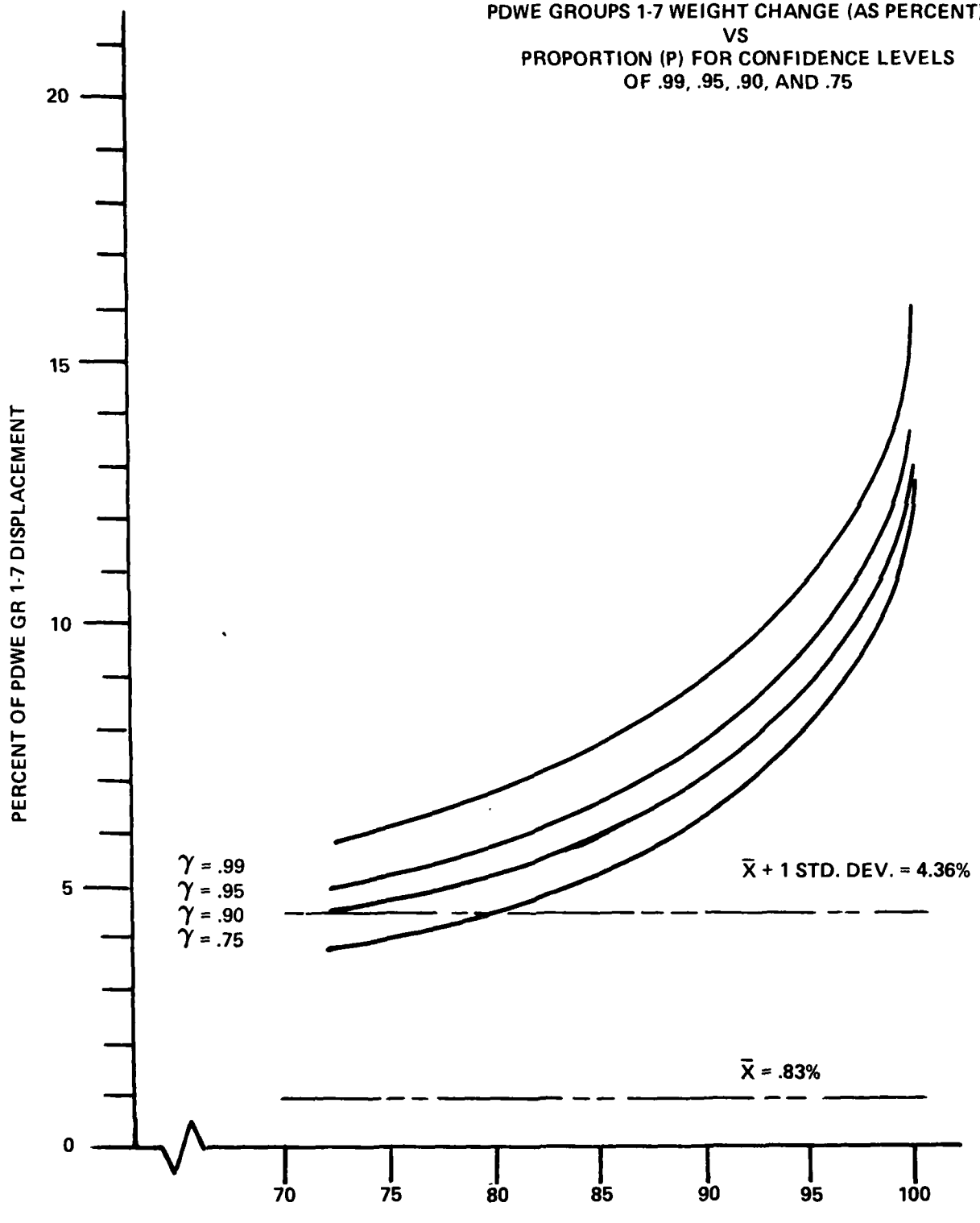

GOVERNMENT FURNISHED MATERIAL MARGIN
EQ CHANGE (as Percent)
VS
CORE GROUPS 1-7 DISPLACEMENT
- Auxiliary Ships
- Amphibious Ships
- Combatant Ships & Patrol Craft
PERCENTAGE
GROUPS 1-7 DISPLACEMENT (TONS)

FIGURE 8

PRELIMINARY/CONTRACT DESIGN MARGIN

PDWE GROUPS 1-7 WEIGHT CHANGE (AS PERCENT)
VS
PROPORTION (P) FOR CONFIDENCE LEVELS
OF .99, .95, .90, AND .75



PROPORTION (P) AS PERCENT OF TRUE POPULATION INCLUDED
BELOW UPPER LIMIT (X_u) AT CONFIDENCE LEVELS (γ) INDICATED.

FIGURE 9

DESIGN AND BUILDING MARGIN

CDWE GROUPS 1-7 WEIGHT CHANGE (AS PERCENT)
VS
PROPORTION (P) FOR CONFIDENCE LEVELS
OF .99, .95, .90, AND .75

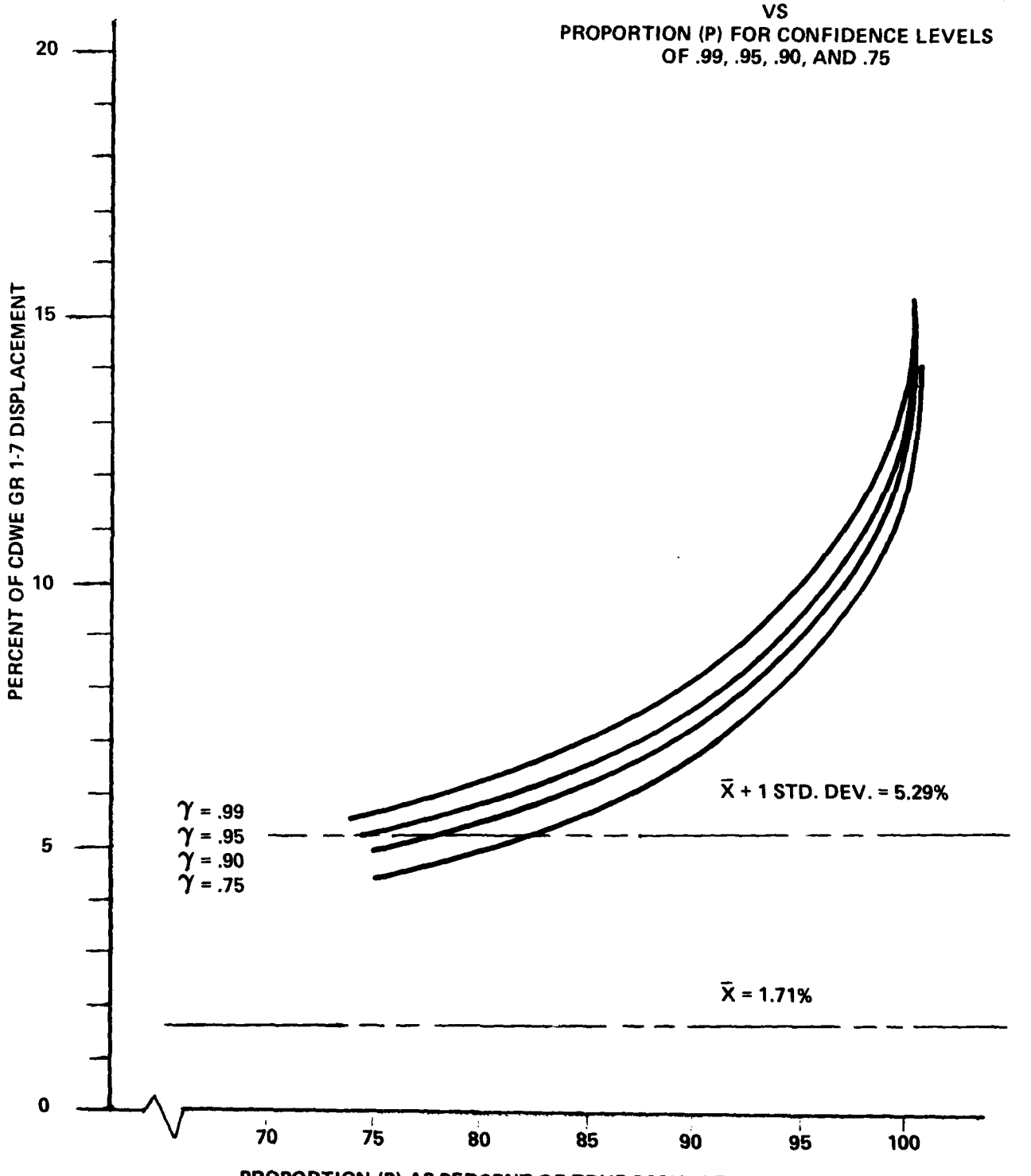
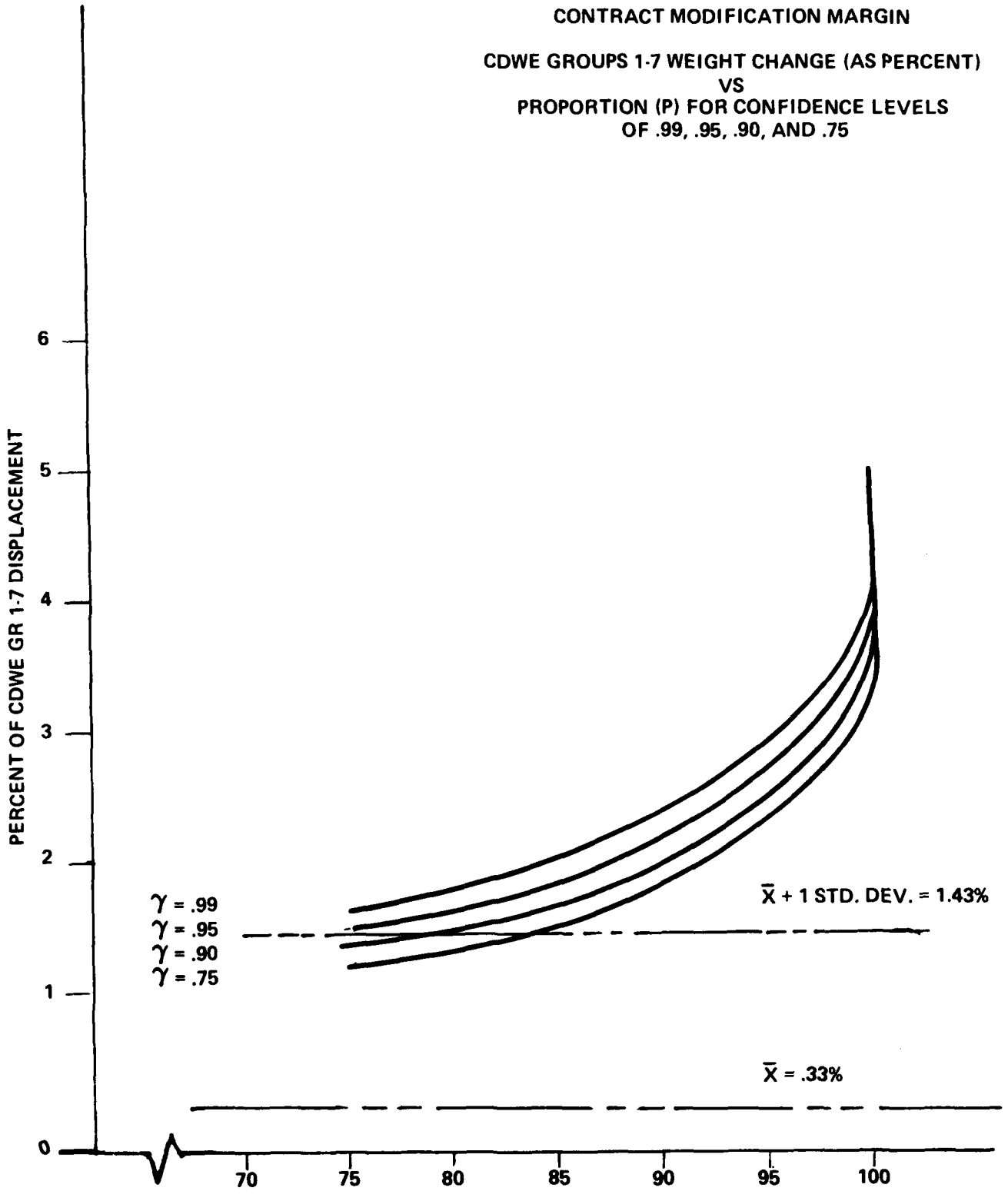


FIGURE 10

CONTRACT MODIFICATION MARGIN

CDWE GROUPS 1-7 WEIGHT CHANGE (AS PERCENT)
VS
PROPORTION (P) FOR CONFIDENCE LEVELS
OF .99, .95, .90, AND .75



PROPORTION (P) AS PERCENT OF TRUE POPULATION INCLUDED
BELOW UPPER LIMIT (X_u) AT CONFIDENCE LEVELS (γ) INDICATED.

FIGURE 11

GOVERNMENT FURNISHED MATERIAL MARGIN

CDWE GROUPS 1-7 WEIGHT CHANGE (AS PERCENT)
VS
PROPORTION (P) FOR CONFIDENCE LEVELS
OF .99, .95, .90, AND .75

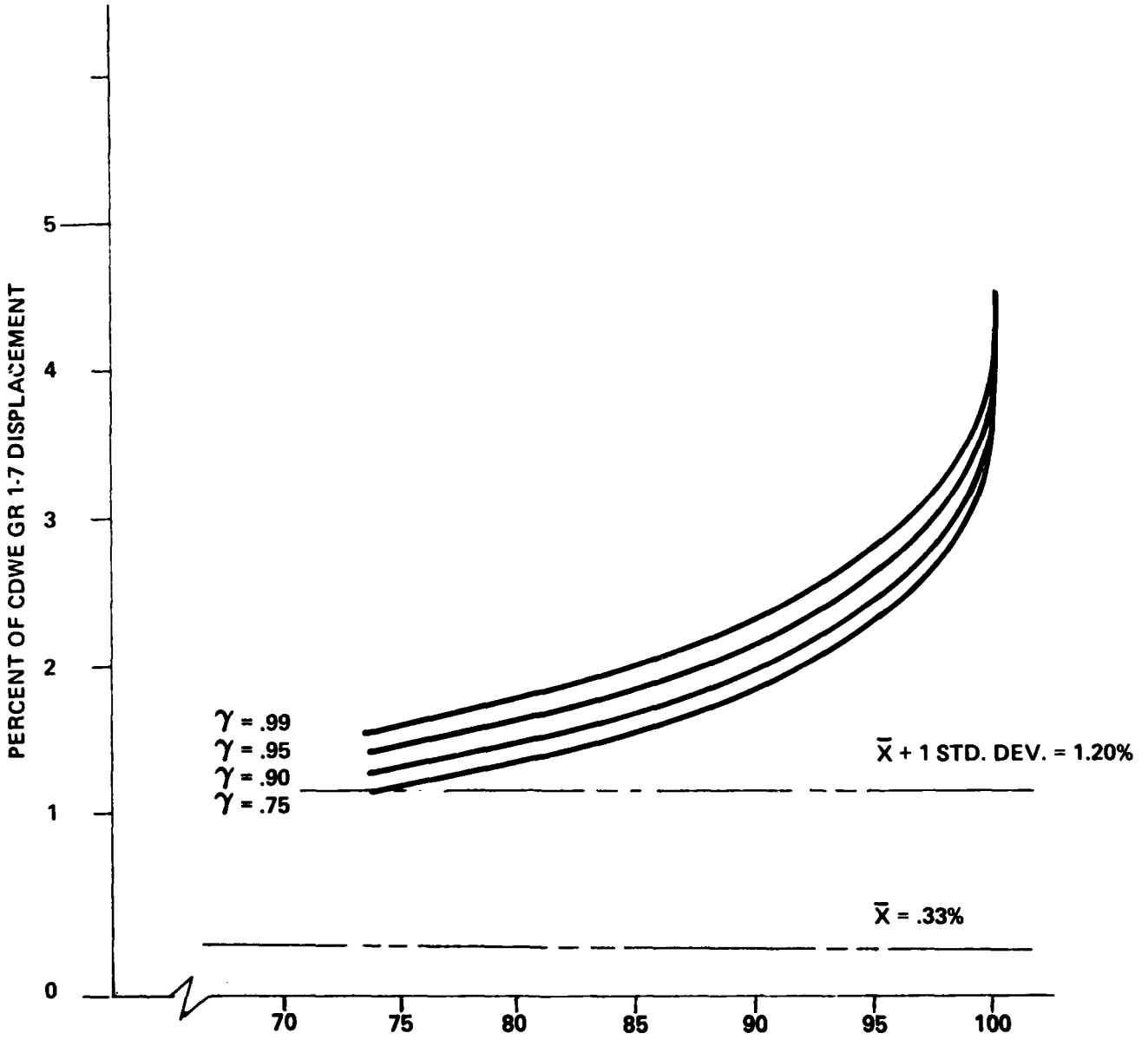
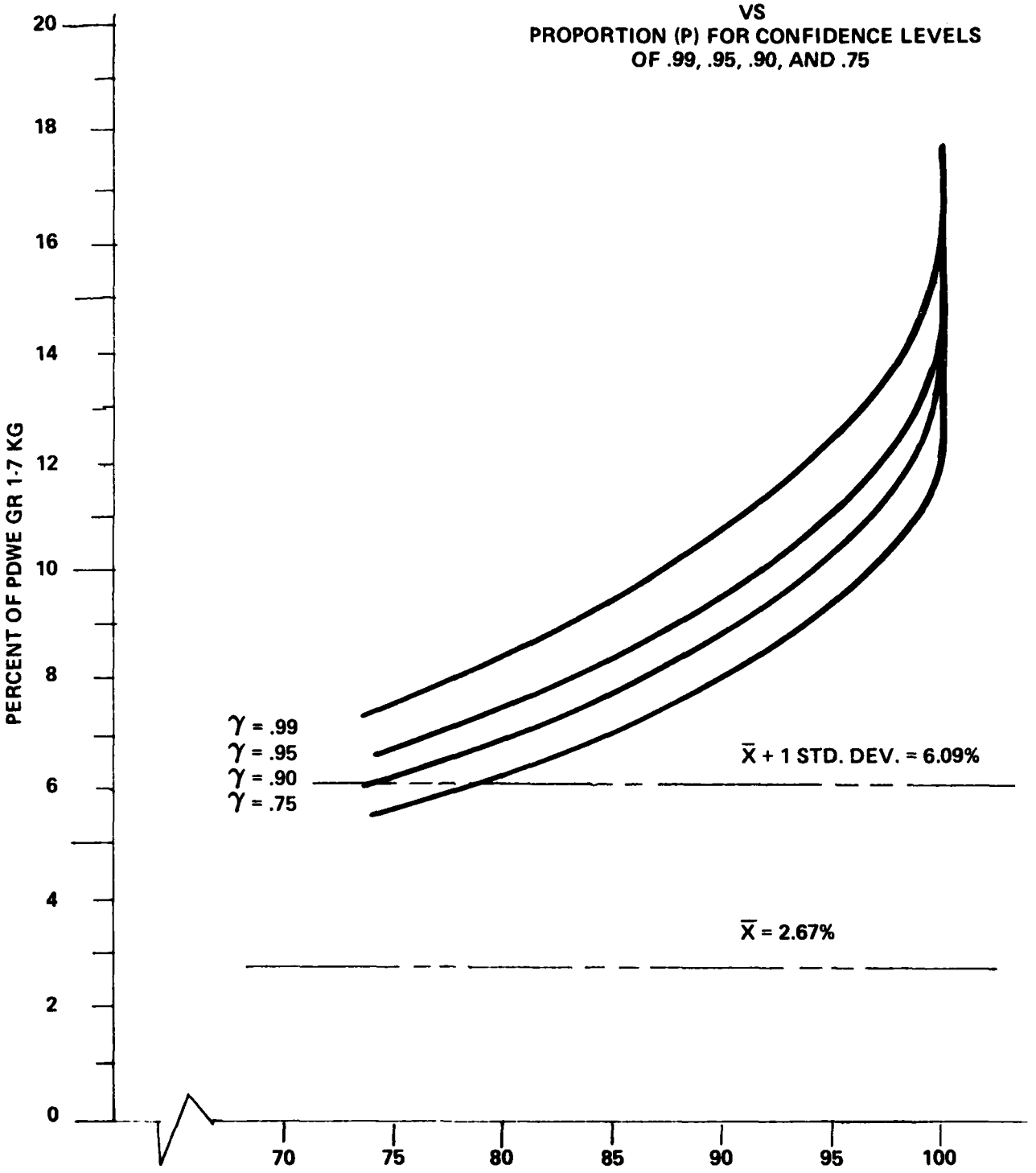


FIGURE 12

PRELIMINARY DESIGN/CONTRACT DESIGN MARGIN

PDWE GROUPS 1-7 KG CHANGE (AS PERCENT)
VS
PROPORTION (P) FOR CONFIDENCE LEVELS
OF .99, .95, .90, AND .75

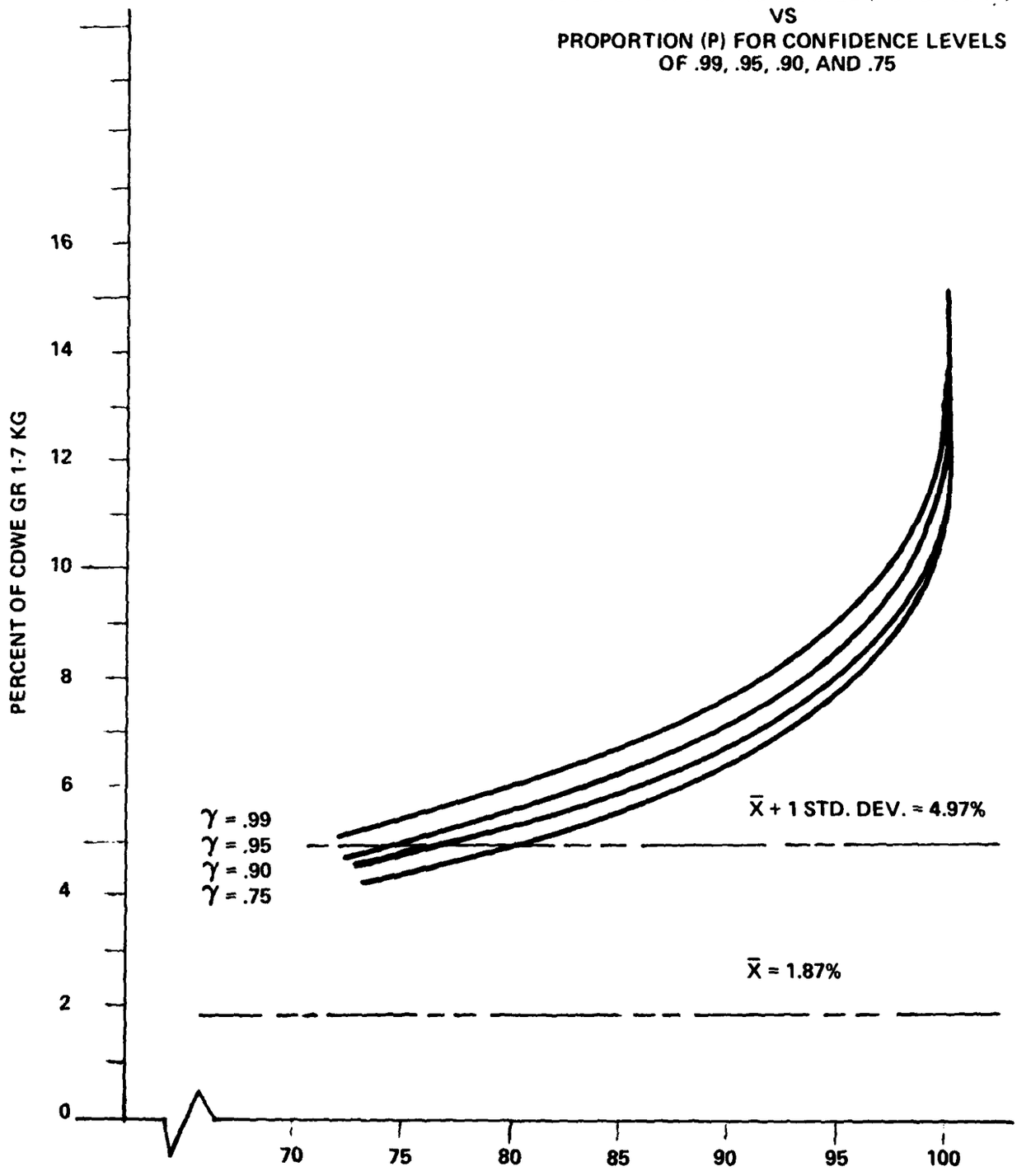


PROPORTION (P) AS PERCENT OF TRUE POPULATION INCLUDED BELOW UPPER LIMIT (X_u) AT CONFIDENCE LEVELS (γ) INDICATED.

FIGURE 13

DESIGN AND BUILDING MARGIN

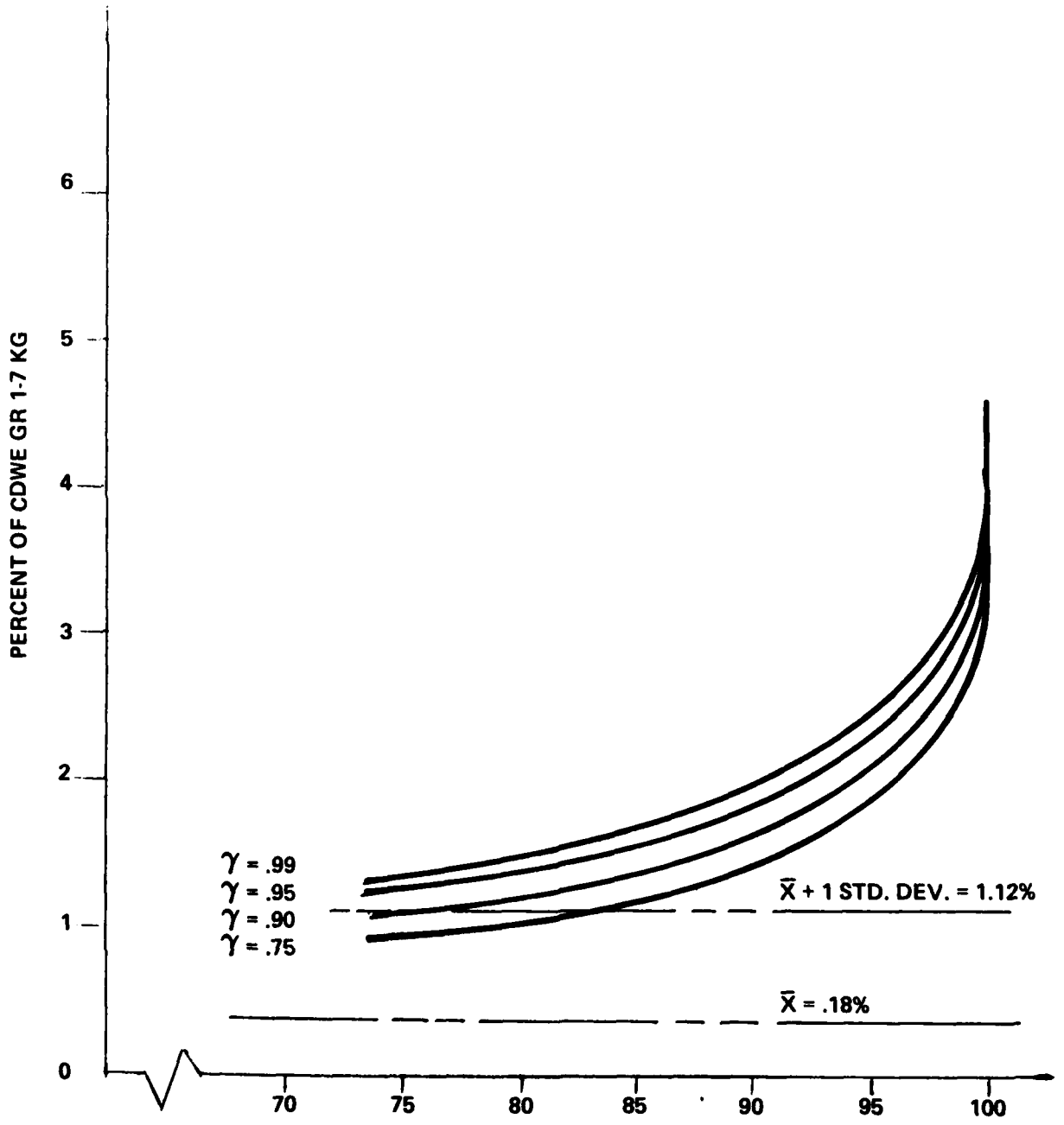
CDWE GROUPS 1-7 KG CHANGE (AS PERCENT)
VS
PROPORTION (P) FOR CONFIDENCE LEVELS
OF .99, .95, .90, AND .75



PROPORTION (P) AS PERCENT OF TRUE POPULATION INCLUDED
BELOW UPPER LIMIT (X_u) AT CONFIDENCE LEVELS (γ) INDICATED.

FIGURE 14

CONTRACT MODIFICATION MARGIN
CDWE GROUPS 1-7 KG CHANGE (AS PERCENT)
VS
PROPORTION (P) FOR CONFIDENCE LEVELS
OF .99, .95, .90, AND .75

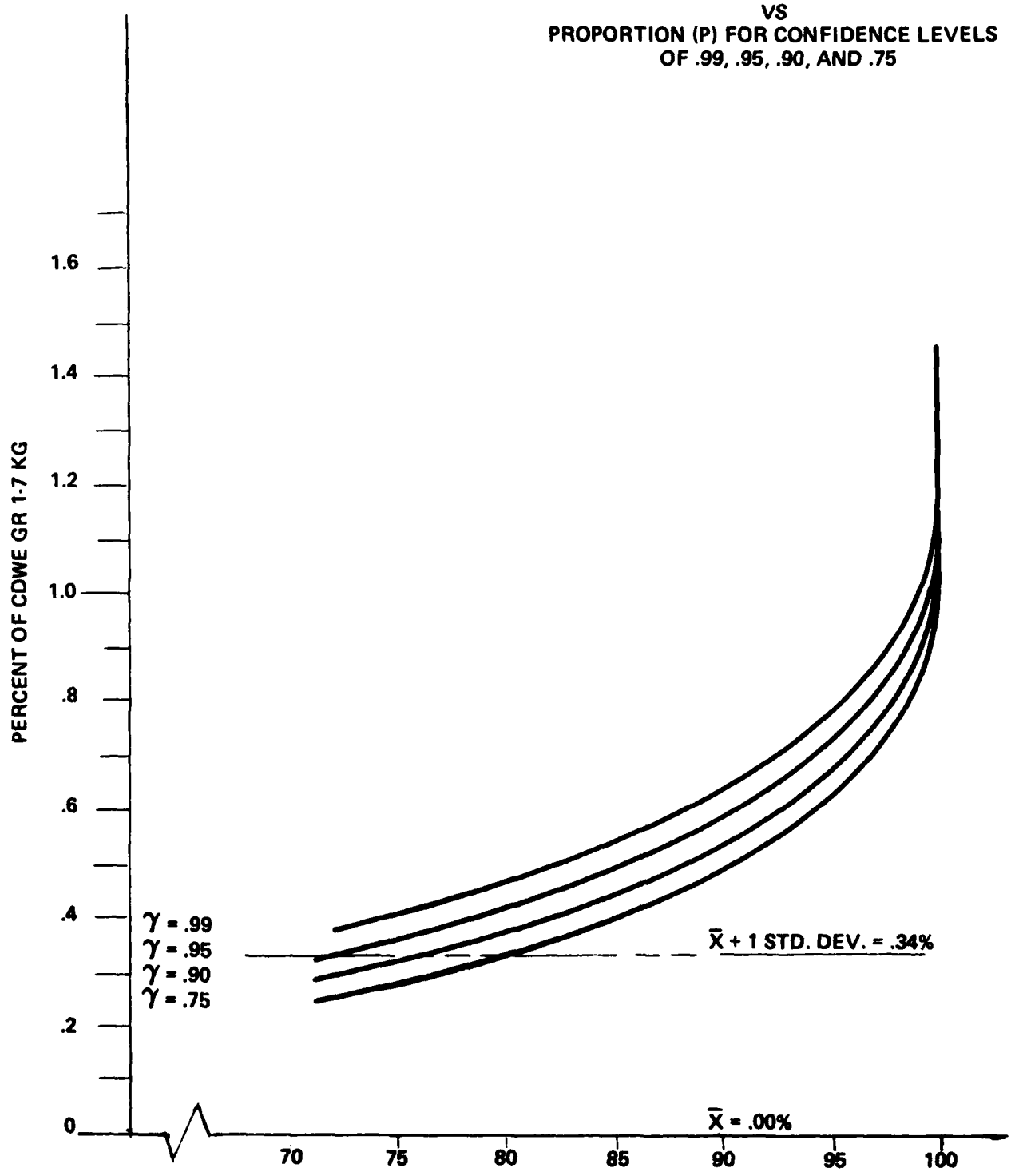


PROPORTION (P) AS PERCENT OF TRUE POPULATION INCLUDED
BELOW UPPER LIMIT (X_u) AT CONFIDENCE LEVELS (γ) INDICATED.

FIGURE 15

GOVERNMENT FURNISHED MATERIAL MARGIN

CDWE GROUPS 1-7 KG CHANGE (AS PERCENT)
VS
PROPORTION (P) FOR CONFIDENCE LEVELS
OF .99, .95, .90, AND .75



PROPORTION (P) AS PERCENT OF TRUE POPULATION INCLUDED
BELOW UPPER LIMIT (X_u) AT CONFIDENCE LEVELS (γ) INDICATED.

FIGURE 16

BUSHIPS CODE 410 MARGIN POLICY

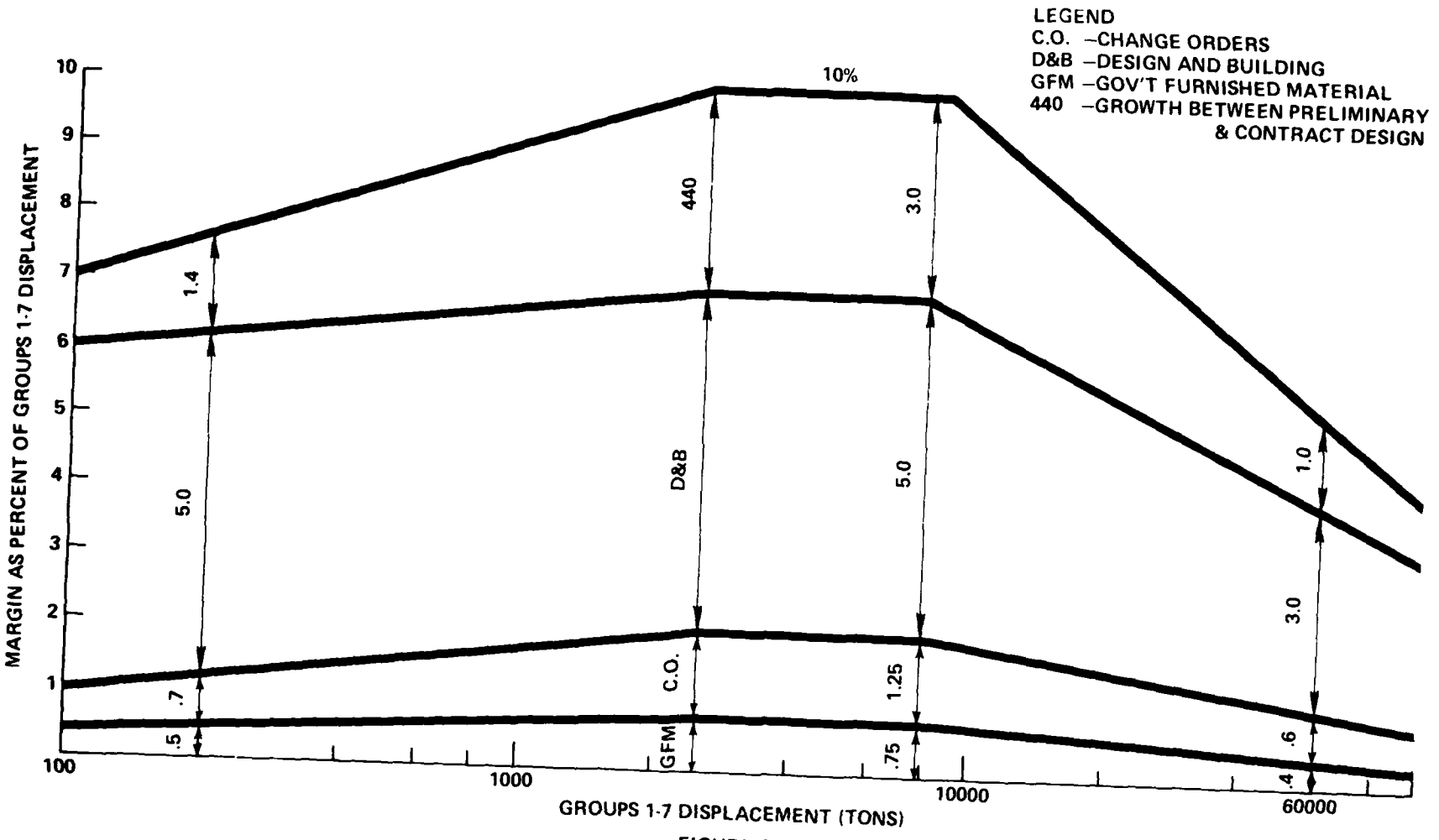


FIGURE 17